Technical Bulletin 118 August 1936

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STUDIES ON THE PHYSIOLOGY OF REPRODUCTION IN THE SHEEP[1] IV. FETAL DEVELOPMENT[2]

LAURENCE M. WINTERS and GEORGE FEUFFEL

INTRODUCTION

The normal rate of prenatal development in farm animals has received practically no attention. This is rather surprising, because market animals have lived one third to one half their lives by the time they are born.

Farm animals are called upon to reproduce under a great variety of environments. What effect varying environments of the dam may have upon both prenatal and postnatal development is unknown. Observations, surveys, and some experimental work indicate that unsatisfactory environments have unfavorable effects on the young organisms. It is futile to study abnormal development without an adequate description of the normal for comparison. The establishment of the normal rate of prenatal development will also be useful as a guide for estimating the age of both pathological and normal specimens obtained from packing plants and farmers.

OBJECTS

The objects of this experiment were:

1. To determine the normal prenatal development in the sheep during the fetal period.
2. To compare the development of fetuses from different sized ewes.
3. To compare the development of fetuses from ewes fed on different planes of nutrition.

LITERATURE REVIEWED

A great amount of study has been devoted to the prenatal growth of small animals. References to the more important of these are included in the bibliography. On very small material such as the fetuses of the rat and opossum, it is extremely difficult to observe accurately the size of the various body parts. The curves showing the relationship of weight to age and length to age are strikingly similar in all the studies of the small animals reviewed.

The prenatal growth of primates, including man, has received considerable study (Jackson, 1909; Streeter, 1920; Schultz, 1926; Scammon and Calkins, 1929; and Scammon and Klein, 1930). These studies have been especially valuable in establishing methods of procedure. Nevertheless, many of the human specimens are of uncertain age and likely to be pathological, both of which tend to obscure the results.

Unless the prenatal specimens are of known age, the value of the material is greatly reduced. With the exception of the studies on the pig

[1] For previous papers in this series see Clark (1934) and Green and Winters (1935) in literature cited.

[2] This study was financed in part by Graduate School Research Funds.

by Warwick (1928) and on cattle by Hammond (1927) and Kislovsky and Larchin (1931), little has been reported upon known-aged prenatal specimens in farm animals. Lowrey (1911) studied the prenatal growth of the pig, but his material was obtained from packing houses; hence it was of unknown age. Curson and Quinlan (1934) report approximate weights and crown-rump lengths in Merino sheep fetuses of various known ages from 33 to 108 days. Their material, however, had been preserved in 10 per cent formalin for some time, and in several cases it was packed rather tightly in containers. This treatment is apt to introduce large experimental errors. These investigators calculated the age of the fetuses from the time of copulation, without regard to the passing of heat. Quinlan and Mare (1931) have stated that time of ovulation "rarely takes place before the 36th to the 40th hour of oestrus." The results of Green and Winters (1935) are somewhat similar; but they found that ovulation occurs near the close of heat. Furthermore, in the Minnesota experiments where the prenatal development of the sheep is being studied intensively, heat in the ewe has been found to be subject to considerable individual variations (24 to 48 hours). The authors, therefore, believe that the age of the fetus is more accurately measured from the cessation of heat rather than from its onset or the time of copulation. Curson and Quinlan, however, were primarily interested in the situation of the developing fetus and not in its weight and length.

So far as the authors are aware, no studies have been reported on the prenatal growth of the various body dimensions of farm animals. Lowrey (1911) studied growth in weight of the head, trunk, and limbs of the cat fetus. Mitchell and associates (1931) have published data on weights of the various internal organs of pig fetuses, ranging in age from 5 to 16 weeks. Their study, however, was from a chemical approach.

Factors affecting fetal development.—So much literature has accumulated regarding environmental factors affecting fetal development that a review of the literature will not be included. The factors which have been suspected, and have received some support from experimental data, of affecting fetal development are: nutrition of dam, size of dam, age of dam, order of pregnancy, size of litter, and sex of fetus.

EXPERIMENTAL PROCEDURE

Treatment of the ewes.—Forty-six mature grade Shropshire ewes were used for this experiment. They were put in good physical condition by being fed rather liberally for one month previous to breeding and then were bred to a Hampshire ram.

The ewes were divided into three groups. Group I consisted of 16 large-framed, rangy ewes with an average weight of 151.37 pounds. The 15 ewes in Group II were smaller, more compact and shorter legged, with an average weight of 122.46 pounds. The 15 ewes in Group III were similar in type to those in Group II, but they were slightly smaller, having an average weight of 114.60 pounds.

At the time of allotment the ewes in Groups I and II were in high enough condition for breeding ewes. The ewes in Group III were somewhat under-conditioned. One objective in the experiment was to contrast

the size of fetuses recovered from Groups I and III on the basis of size and type of dams, and another was to contrast the fetuses from Group II with Group III on the basis of condition of dam. An attempt was made to maintain Group I at the original weight; to have Group II fatten continuously; and to get Group III in about the same condition as Group I.

The objective was to introduce no wider differences in the rations than appeared necessary in order to accomplish the above purposes. The ewes were weighed individually at the time of allotment and at frequent intervals thereafter in order to get each group on the proper level of nutrition. The rations were changed about considerably in order to obtain the proper level of nutrition. The following were finally settled on:

Group I. Prairie hay ad lib.
Group II. Alfalfa hay, shelled corn, and linseed meal.
Group III. Prairie hay ad lib. with a light feed of alfalfa hay and shelled corn.

It was necessary to vary the proportions for Groups II and III from time to time, dependent upon changes in temperature. The ewes had access to water and salt at all times. Potassium iodide was added to the water. The average weights at time of slaughter showed that Group I had gained an average of 0.22 pound per ewe. When the weights of the fetuses and fetal membranes are taken into consideration, these ewes had lost in weight, altho they were still in satisfactory condition for breeding ewes. Group II gained an average of 30.83 pounds. They were very fat. Group III gained an average of 11.56 pounds. They were in excellent condition, possibly slightly higher than that of the ewes in Group I.

Breeding the ewes.—The oestrus cycle of each ewe was established previous to mating. This was done by testing the ewes four times daily (6 a.m., 12 a.m., 4 p.m., and 8 p.m.).

The ewes were served near the end or at the end of the second heat period. Previous work at Minnesota has shown that the duration of heat in one cycle coincides very closely with that of the following cycle. Previous work has shown also that ovulation occurs approximately as the ewe is passing from heat with a small range on either side. It is, therefore, highly probable that the fetuses of this study are close to the ages indicated.

Division of fetal period.—The slaughtering schedule of the ewes was arranged so that 15 stages of fetal development would be recovered, a ewe from each group being taken for each stage. This method provided from three to six fetuses for each respective stage, according to whether the ewes carried single or twin fetuses.

The first stage of development studied was at 34 days after fertilization. This approximates the beginning of the fetal period. (Previous studies in this laboratory had already carried prenatal development of the sheep to the 34th day.) The last stage recovered was 140 days, or approximately eight days before birth. The intermediate stages were 36, 38, 42, 46, 52, 58, 66, 74, 84, 94, 104, 116, and 128 days. The intervals between the stages were gradually widened as age increased. Short intervals were taken between the early stages because development is very rapid at this time.

Procedure in measuring fetuses, uteri, etc.—The uterus was removed soon after slaughter and all fat trimmed off. The number of corpora lutea and the number of ovaries involved were noted. The broad ligament was trimmed off and the cervix cut at the circular depression about its middle. The uterus and contents were then weighed. The uterus was opened carefully to prevent damage to the fetus. The fetus surrounded by the amnion was exposed. The amnion was then punctured and removed carefully with forceps. The umbilical cord was tied close to the belly and clipped with a haemostat before being severed. The fetus was held suspended for a short time to allow the excess fluid to drain from it. The fetus and haemostat were then weighed to the nearest centigram and the weight of the haemostat subtracted.

After the 84-day stage the external moisture on the fetus was wiped off, and the remainder on the skin was allowed to evaporate before the fetus was weighed. The free fluid in the mouth and nostrils was allowed to drain off before weighing. With the more mature stages it was necessary to wash all mucous and excretory material from the short wool. The wool was then thoroly rubbed with dry cloths until it was practically dry. These stages were weighed to the nearest gram.

For the 34- to 64-day stages the fetal membranes and the uterus were weighed separately. The total weight of the membranes, uterus, and fetus (or fetuses) was subtracted from the weight of the unopened uterus to give the weight of the uterine fluid. In the early stages it was simple to separate the fetal membranes from the uterus; but as gestation advanced, it became increasingly difficult to separate them with any degree of accuracy. Therefore, in the later stages the membranes and uterus were weighed together.

In taking the body measurements, great care was taken to have all fetuses in the same relative position. The Schultz (1929) technique for measuring the outer body of primate fetuses was used as a guide. Several measurements Schultz had listed as important were taken in the hope they might be useful for comparison. A number of the measurements included (Table 1) were started after the early stages of development had passed; the change and development of the various body parts showed them to be rather definite. Several were started and later discarded, because they proved too indefinite.

DESCRIPTION OF MEASUREMENTS

Weight.—This was taken in grams and fractions thereof in the early stages, but to the nearest gram toward the close of the fetal period. This is one of the most satisfactory measurements of fetal development.

Volume.—On the early stages this was taken by suspending the fetus with a thread and recording the displacement in a graduated measuring jar. After the 84-day stage, it became necessary to measure the volume by catching the water displaced by the suspended fetus as it siphoned off from a metal tank through a glass tube held in position by a clamp. The measurements of volume on the early stages appeared very accurate; but less so on the larger fetuses. However, in the absence of a satisfactory scale, a very close approximation of size can be obtained by taking the volume of water displaced.

Forehead-rump length.—This dimension was taken with a steel caliper by measuring from the forehead to the pin bone. Crown-rump length is a standard measure in primates. In the later stages of sheep the crown becomes a rather indefinite point to measure from. The forehead is a definite point all through fetal development. Care must be taken, however, to prevent the head curling tailward. Every fetus was put in the same position before the measurement was taken; viz., on its left side with its back towards the investigator and with its back along a straight edge. The relative positions of the head and legs to the body were always as nearly the same as possible. This is a very satisfactory measure of fetal development; it and weight are the most satisfactory measures of gross development.

Tail head to line joining ears.—The line joining the ears is imaginary, but it can be fixed with considerable accuracy. A pin inserted through the skin was used to mark this point. Another pin was used to mark the position of the tail head, which was located by palpating for the joint between the third and fourth coccygeal vertebrae. This was found to be a very satisfactory measurement.

Trunk length.—This is a measurement of the main body of the fetus. It is a rather unsatisfactory measurement, since no points are fixed.

Shoulder point to pin bone.—This was taken from the shoulder point to the pin bone; it is a measurement of body length. An endeavor was made to have the legs of the fetus always in the same relative position, because variations in this regard tend to introduce inaccuracies. This is essentially the same measurement as trunk length, and it is more definite.

Shoulder point to hip bone.—This dimension is very similar to the above and when subtracted from it gives an indication of growth from the hips to the pins. It is recognized that the subtraction is not strictly accurate, since the pins, hips, and shoulder point are not on a straight line.

Hip bone to pin bone.—This dimension was obtained by subtracting the length of shoulder point to hip bone from shoulder point to pin bone. It is not accurate, but nevertheless the figures obtained give a good idea of the growth in that region.

Withers to tail head.—Both these points were fixed with pins before the measurement was taken. In the very young stages both these points are rather indefinite, but later on they become very definite.

Neck length.—This, like trunk length, is somewhat indefinite, but the results appeared reasonably accurate.

Shoulder breadth.—This is a difficult measurement to take accurately, especially in the later stages. The measurement was taken with a caliper. In the older stages it was necessary to suspend the fetus by its hind legs to get uniformity for the measure.

Hip breadth.—This measurement was somewhat indefinite on the young fetuses but became more accurate and more easily taken on the older specimens. It was taken with a caliper.

Medium neck circumference.—All measurements of circumference were taken with a fine linen thread. A knot was tied on the thread and a fine pair of forceps used to catch the thread at the point opposite

the knot. The thread was then laid along a steel rule and the circumference read directly. Three readings were taken and averaged.

Chest circumference.—This was taken just back of the forelegs. It is a very satisfactory measurement.

Abdomen circumference.—The thread was passed about the body at a point just ahead of the umbilical cord. It is a very useful measurement.

Foreleg circumference.—The point of measurement was halfway between the knee and first pastern joint.

Horizontal head circumference.—This is the greatest horizontal circumference of the head; it is taken across the glabella. It is easily taken in young specimens by means of a linen thread, but it was necessary to use pins on the more advanced stages to prevent the thread from slipping. Four pins were used, two close to the base of the ears and the other two over the eye region of the skull.

Head height (chin-crown).—This measurement is used to study head growth in humans. It is taken from beneath the chin to the top of the crown. It is easily taken.

Head breadth.—Head breadth is taken with a caliper at points just in front of the ears. It is easily taken on the young stages but becomes rather inaccurate on the older stages due to the wool and loose skin.

Face height.—This is a projected measurement from the line joining the inner corner of the two eyes to the point of the chin.

Inner-eye breadth.—A small sliding caliper was used to obtain this measurement. It is essentially the same as Schultz' (1929) inner-eye breadth.

Forearm length.—Unless the specimen is dissected, this measurement is subject to considerable error.

Knee to hoof point.—This is taken from the knee joint to the point of the hoof. It is taken rather easily.

Knee to coronary band.—Considerable difficulty was encountered in taking this measurement until sufficient ossification had set in.

Leg length (tibia).—This measurement is taken from the proximal end of the tibia to the hock joint.

Hock to hoof point.—This is essentially the same as from knee to hoof point.

Hock to coronary band.—This is similar to knee to coronary band.

Tail length.—This measurement was taken from the tail head (fixed by a pin on the larger fetuses) to the tip of the tail. In the early stages the tail was laid on a piece of moist thick paper; in the later stages it was laid on a piece of soft wood and impaled in position until the measurement was taken. Wool, when it appeared, was clipped off the tail before measuring.

A summary of the measurements by ages is presented in Table 1. With it as a guide, a fairly close estimate of the age of a normal sheep fetus can be made. The measurements that will be most useful in estimating unknown ages are weight, forehead-rump length, chest circumference, and abdominal circumference. In instances where retarded development is suspected, the more detailed measurements may be useful.

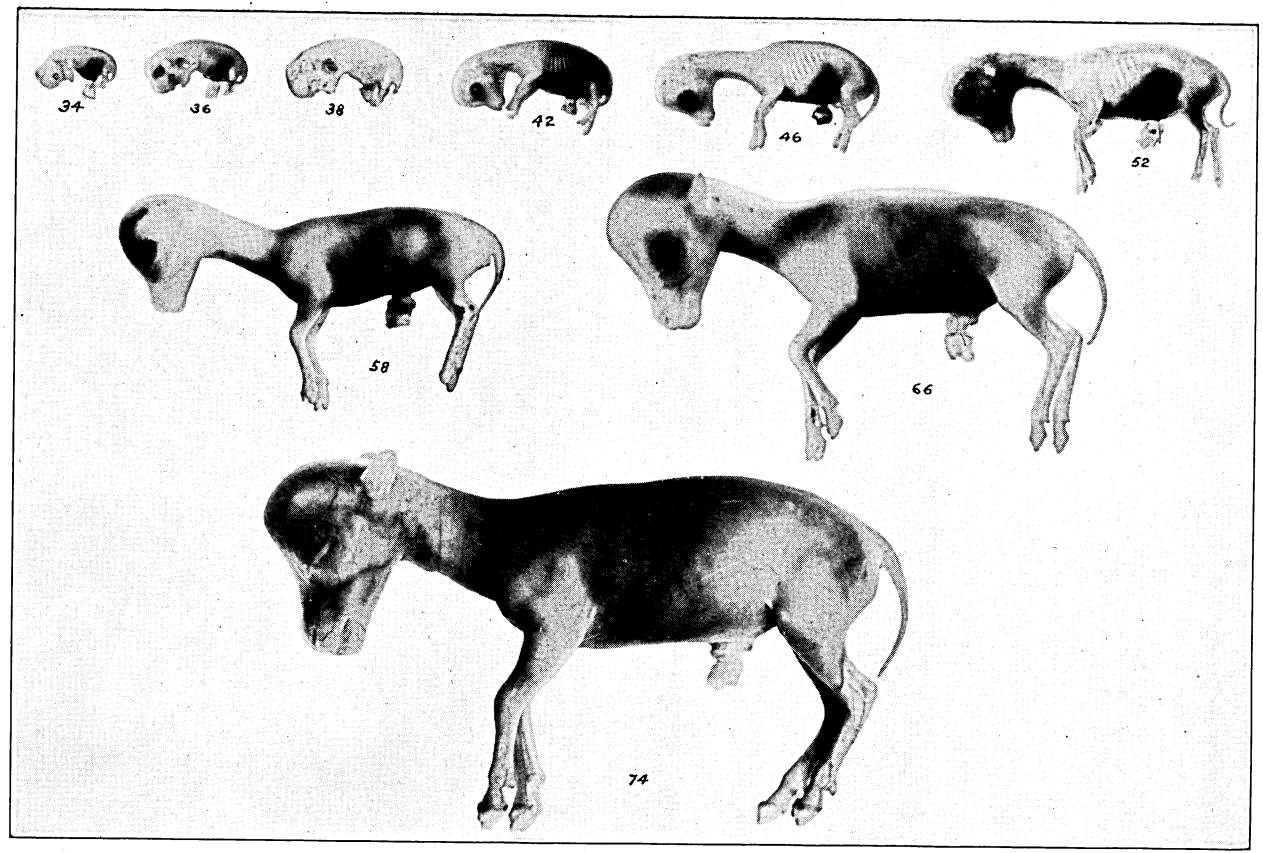

FIG. 1. MORPHOLOGICAL CHANGES OF THE SHEEP FETUS FROM 34 TO 74 DAYS
Age by days indicated below each stage. (Reduced x 0.41)

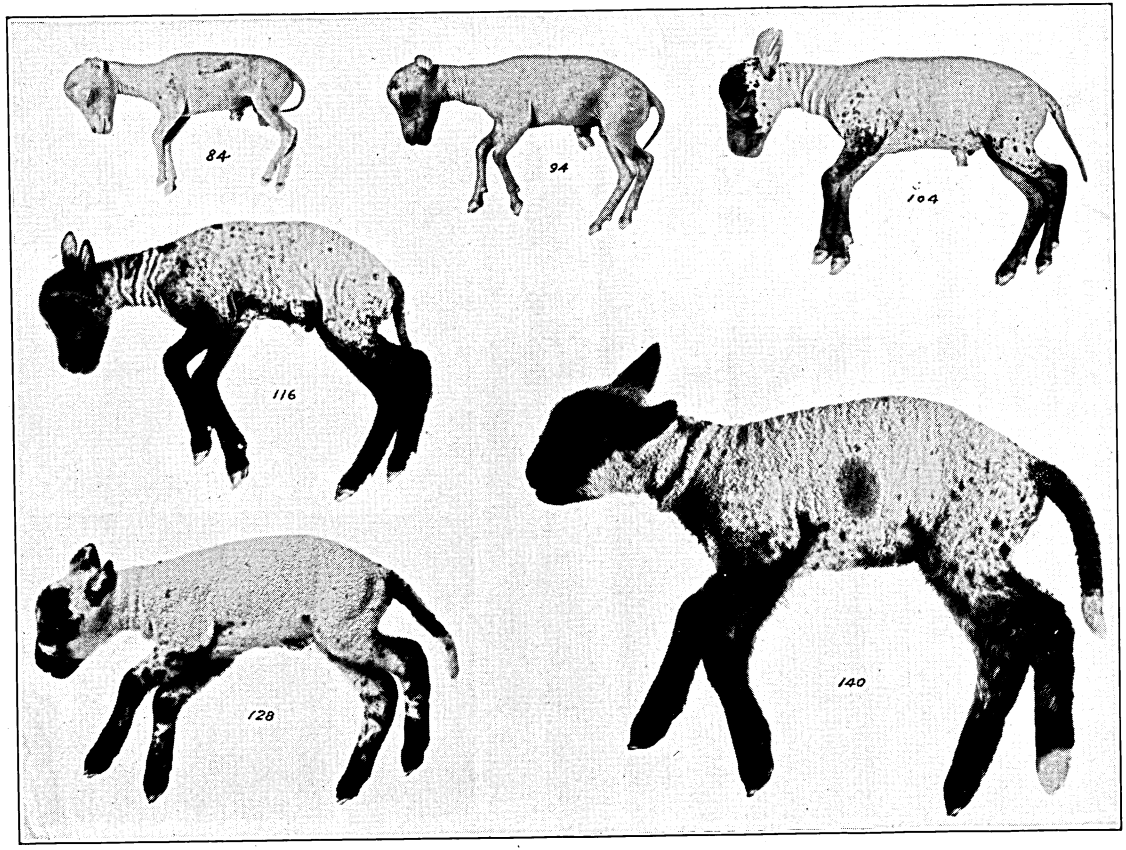

FIG. 2. MORPHOLOGICAL CHANGES OF THE SHEEP FETUS FROM 84 TO 140 DAYS
Age by days indicated below each stage. (Reduced x 0.13)

Table 1.—Average Weight and Measurements o

Age of fetus	No. of fetuses	Average weight	Average volume	Average forehead-rump length	Tail head to line joining ears	Average trunk length
days		gm.	cc.	cm.	cm.	cm.
34	3	2.20	1.67	3.12	.....	1.90
36	5	3.52	2.92	3.80	2.98	2.27
38	6	4.69	3.77	4.23	.....	2.55
42	4	7.33	6.58	5.36	4.10	3.02
46	5	15.34	13.60	7.44	.....	4.41
52	5	31.75	30.00	9.55	7.90	5.83
58	5	64.29	62.60	12.13	10.12	7.49
66	4	128.89	117.25	15.05	12.30	9.33
74	6	236.60	224.33	19.18	15.93	12.08
84	4	439.66	409.50	23.69	19.79	15.33
94	6	762.73	692.33	28.19	23.70	18.20
104	4	1244.55	1166.75	33.25	27.96	21.79
116	3	2086.33	2045.00	38.43	33.00	25.38
128	6	2713.00	2717.67	42.89	37.20	29.93
140	7	3393.00	3295.86	43.91	39.33	30.53

Age of fetus	No. of fetuses	Abdomen circum-ference	Foreleg circum-ference	Horizontal head circum-ference	Head height	Head breadth
days		cm.	cm.	cm.	cm.	cm.
34	3	3.28	0.56	2.70	1.07	0.70
36	5	3.72	0.59	3.30	1.35	0.82
38	6	4.41	.....	3.43	1.35	0.94
42	4	4.70	0.68	4.23	1.78	1.19
46	5	5.97	0.76	5.36	2.36	1.51
52	5	7.92	0.90	6.73	3.18	1.93
58	5	9.95	1.14	7.98	4.02	2.33
66	4	12.68	1.36	9.55	4.93	2.74
74	6	15.28	1.74	11.49	6.08	3.36
84	4	18.66	2.16	13.39	7.46	4.03
94	6	22.72	2.75	15.63	8.69	4.48
104	4	26.75	3.64	18.29	9.74	4.89
116	3	31.55	4.87	21.33	10.98	5.32
128	6	33.28	5.05	22.73	12.03	5.83
140	7	35.30	5.06	23.14	12.34	6.01

the Sheep Fetus in Relation to Age

oulder int to bone	Hip bone to pin bone	Withers to tail head	Neck length	Shoulder breadth	Hip breadth	Neck circum-ference	Chest circum-ference
cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
.....	.....	.....	.....	0.77	0.65	.....	2.68
.....	.....	.....	.....	0.85	0.72	2.15	3.21
.....	.....	.....	.....	0.94	1.03	.....	3.30
.....	0.49	2.35	1.75	1.11	0.96	2.40	4.14
.....	.....	.....	.....	1.29	1.21	.....	5.26
.....	.....	4.85	3.05	1.78	1.34	3.78	6.57
.....	.....	6.15	3.97	2.24	1.59	4.46	8.29
7.13	2.04	7.96	4.34	2.76	2.09	5.80	10.65
8.88	2.59	9.93	6.00	3.54	2.47	7.51	13.58
0.94	3.49	12.66	7.13	3.98	3.00	8.89	16.39
3.26	4.00	14.78	8.93	4.65	3.56	10.16	19.70
5.75	4.64	17.23	10.74	5.30	4.21	12.16	23.53
8.65	5.85	20.88	12.12	5.85	4.90	14.18	28.17
1.64	7.27	23.21	13.99	6.48	5.18	16.23	31.08
2.24	7.19	24.86	14.47	6.44	5.76	17.45	33.60

nner-eye readth	Forearm length	Knee to hoof point	Knee to coronary band	Leg length (tibia)	Hock to hoof point	Hock to coronary band	Tail length
cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
.....	0.37	0.45	0.28	0.37	0.43	0.35	0.78
0.65	0.48	0.51	0.34	0.48	0.55	0.34	0.76
.....	0.58	0.58	0.39	0.59	0.63	0.46	0.91
1.10	0.85	0.74	0.53	0.76	0.89	0.66	1.29
.....	1.15	1.21	0.88	1.10	1.29	1.01	1.65
1.19	1.56	1.69	1.30	1.88	2.05	1.71	2.18
1.44	2.00	2.21	1.74	2.47	2.78	2.32	2.80
1.90	2.66	2.89	2.34	3.06	3.79	3.18	3.84
3.09	3.30	3.95	3.11	3.98	5.08	4.18	4.85
3.65	4.34	5.14	4.06	5.41	6.71	5.65	5.90
4.13	5.62	6.67	5.43	7.15	8.76	7.58	8.32
4.36	6.66	8.69	7.15	8.58	10.90	9.41	10.11
4.82	8.79	10.93	8.97	11.18	13.87	12.12	14.20
4.98	9.66	13.13	10.98	13.07	16.58	14.70	16.64
5.27	10.94	13.45	11.08	13.81	17.86	15.51	17.33

DISCUSSION OF RESULTS

Development of the Fetus

Fetal development in the sheep on the basis of weight is exceedingly rapid between the ages of 34 and 58 days. Plotted on coordinate paper (Fig. 3), this weight increase is not demonstrated with the same effectiveness as when plotted on arithlog paper (Fig. 4). During the period up to 58 days of prenatal age the percentage increase in weight per day is apparently nearly constant, as the section of the curve on arithlog paper between 34 and 58 is almost a straight line. Plotted on coordinate paper, the curve showing the relation between prenatal weight and age of the sheep fetus is very similar to those of the guinea pig, albino rat, and opossum. In swine the curve does not appear to rise so rapidly until near the end of gestation, according to the work of Warwick (1928).

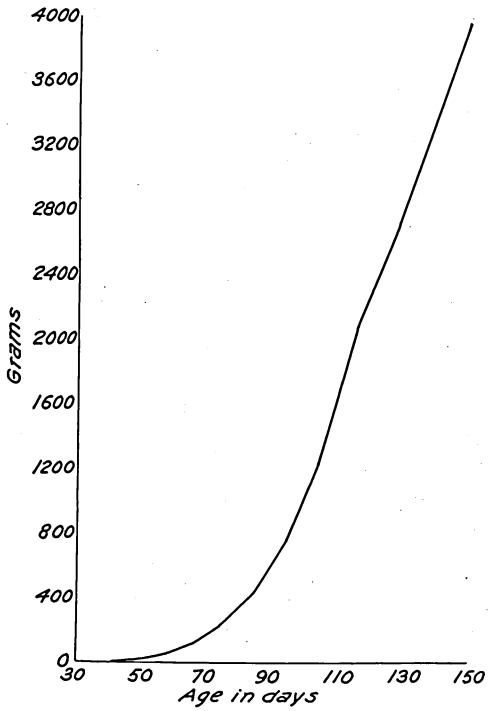

FIG 3. GROWTH OF THE SHEEP FETUS
Weight on age plotted on coordinate paper.
(Contrast with Fig. 4.)

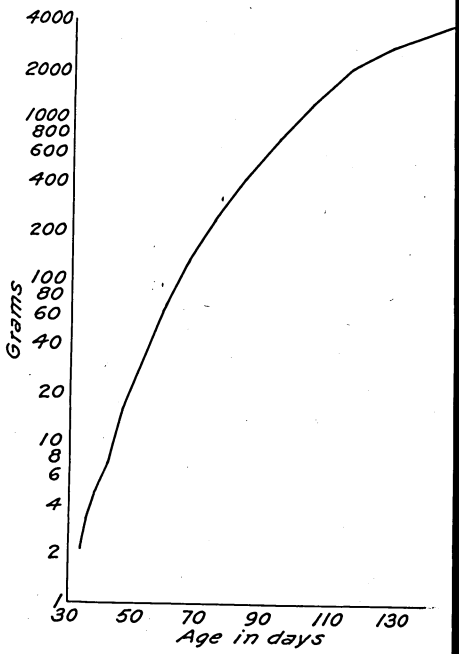

FIG. 4. GROWTH OF THE SHEEP FETUS
Weight on age plotted on arithlog pape
(Contrast with Fig. 3.)

Brody (1927) believes prenatal growth in rats is divided in a number of periods, each being distinguished by its particular constant percentage increase in weight. Kislovsky and Larchin (1931) believe there are four such periods in the prenatal growth of cattle. It is difficult, however, to believe that the percentage rates change as suddenly as the above writers

indicate by the term "break." A gradual decrease of daily percentage increase appears more likely. It is therefore probable that if sufficient numbers of fetuses of every possible age and of definitely known ages were weighed that no such "breaks" as described by these investigators would be evident.

Table 2.—Ratios of Various Body Parts to Forehead-Rump Length

Age of fetus	Chest circumference	Abdomen circumference	Neck length	Hindleg*	Foreleg†
days	1:	1:	1:	1:	1:
34	1.16	0.95	.....	3.67	3.82
36	1.18	1.02	.....	3.71	3.84
38	1.28	0.95	.....	3.48	3.66
42	1.30	1.14	3.06	3.25	3.38
46	1.41	1.25	.....	3.11	3.15
52	1.45	1.21	3.13	2.43	2.94
58	1.46	1.22	3.06	2.31	2.88
66	1.41	1.19	3.47	2.20	2.71
74	1.41	1.26	3.20	2.12	2.65
84	1.45	1.27	3.32	1.95	2.50
94	1.43	1.24	3.16	1.77	2.30
104	1.41	1.24	3.10	1.71	2.17
116	1.36	1.22	3.17	1.53	1.95
128	1.38	1.29	3.07	1.45	1.88
140	1.31	1.24	3.03	1.39	1.80

* Not including femur.
† Not including humerus.

The ratios of body parts to forehead-rump length are interesting (Table 2). Chest circumference is proportionally smaller at the 58-day stage, whereas abdomen circumference is smallest at 128 days. The ratio of neck length to forehead-rump does not change greatly, but it is proportionally shortest at 66 days. Both fore and hind legs increase gradually in proportion to forehead-rump length.

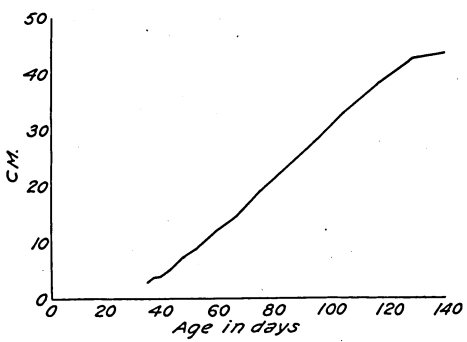

FIG. 5. GROWTH OF THE SHEEP FETUS
Forehead-rump length on age.
(Contrast with Fig. 6.)

When plotted on coordinate paper, forehead-rump length on age shows a constant rate of increase up to 124 days (Fig. 5). Forehead-rump length on weight gives a very different type of curve (Fig. 6). During early development increase in length is proportionally greater than increase in weight. After attaining a weight of about 500 grams the proportionate increase in weight becomes the greater.

The plots (Figs. 7 and 8) of chest and abdominal circumference on age show constant rates of increase up to 116 days. Abdominal growth is more rapid up to 116 days but less rapid thereafter.

Neither the size nor the rations of the ewes had any evident differential effect on the development of fetuses (Table 3). This is not regarded as conclusive evidence that size and ration of the dam have no effect

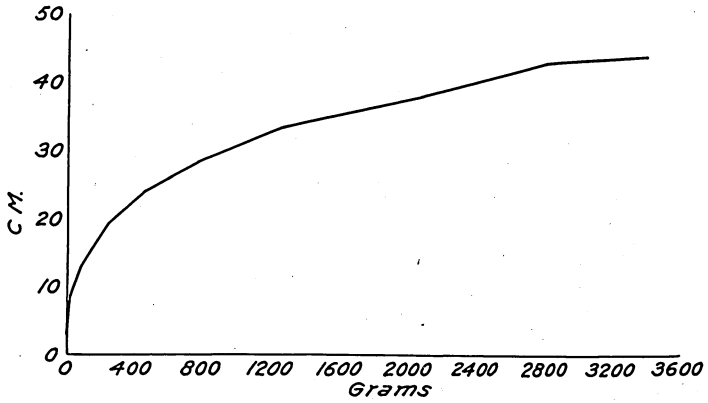

FIG. 6. GROWTH OF THE SHEEP FETUS
Forehead-rump length on weight.
(Contrast with Fig. 5.)

upon the development of the fetus, but that in this instance even tho the differences were large, they were not large enough to have a recognizable effect. It is of interest that one yearling ewe (carried as an extra) had

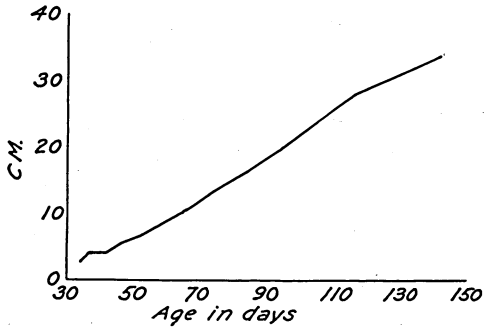

FIG. 7. GROWTH OF CHEST CIRCUMFERENCE IN SHEEP FETUS

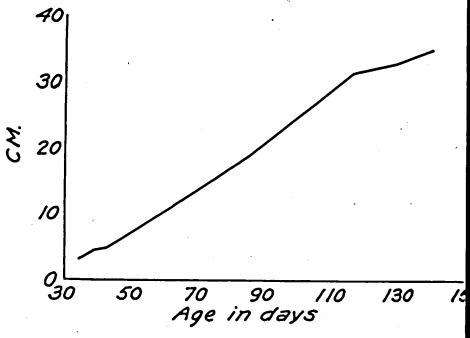

FIG. 8. GROWTH OF ABDOMINAL CIRCUMFEREN IN SHEEP FETUS

a single 38-day fetus of about the same size and weight as each of three single 34-day fetuses from mature ewes.

The numbers by ages are not sufficient to allow a satisfactory com-

parison between single and twin fetuses. In some instances the singles were heavier than the twins, and in other cases the reverse was true. A plot (Fig. 9) of the singles and twins shows an advantage in favor of the singles which becomes more apparent after 110 days. Unpublished data by Winters from another experiment show that at birth singles are significantly heavier than twins.

Table 3.—Increase in Size of Sheep Fetuses by Ages and Groups

Age of fetus	Weight				Forehead-rump length			
	Group I*	Group II	Group III	Average	Group I*	Group II	Group III	Average
days	gm.	gm.	gm.	gm.	cm.	cm.	cm.	cm.
34	1.85	2.90	1.84	2.20	2.90	3.55	2.90	3.12
36	3.77	3.63	3.24	3.52	4.05	3.75	3.70	3.80
		3.79	3.19			3.80	3.70	
38	4.75	4.89	4.74	4.69	4.00	4.45	4.30	4.23
	4.72	4.75	4.27		4.20	4.15	4.30	
		3.32†						
42	6.95	6.90	7.82	7.33	5.20	5.20	5.55	5.36
	7.65				5.50			
46	12.29	16.30	14.75	15.34	7.25	7.40	7.35	7.44
		18.30	15.05			7.70	7.50	
52	35.74	28.76	28.85	31.75	9.60	9.30	9.35	9.55
	35.92	29.50			9.80	9.70		
58	65.25	64.00	57.60	64.29	12.10	12.20	11.90	12.13
	67.77		66.85		12.25		12.20	
66	126.96	111.88	139.45	128.89	14.40	15.25	15.10	15.05
			137.25				15.45	
74	208.18	232.45	258.23	236.61	18.60	18.95	19.95	19.18
	211.68	270.50	238.60		18.85	19.90	18.85	
84	465.90	430.91	453.59	439.66	24.15	23.55	24.20	23.69
			408.23				22.85	
94	752.20	843.50	741.20	762.73	28.40	28.70	28.30	28.19
	764.70	754.20	720.60		28.15	27.75	27.85	
104	1276.00	1295.20	1246.50	1244.55	33.55	34.30	33.45	33.25
	1160.50				31.70			
116	2189.00	2221.00	1849.00	2086.33	38.20	38.90	38.20	38.43
128	2751.00	2345.00	2546.00	2713.00	42.80	42.55	40.90	42.89
	2935.00	3139.00	2562.00		44.05	45.15	41.90	
140	3172.00	3160.00	3995.00	3393.00	43.10	42.60	47.40	43.91
	3146.00	3274.00			43.00	41.65		
	3409.00				44.10			
	3595.00				45.50			

* Group I, ewe, average weight 151 lb.; average gain during trial, 0.22 lb.
Group II, ewe, average weight 122 lb.; average gain during trial, 31.0 lb.
Group III, ewe, average weight 114 lb.; average gain during trial, 12.0 lb.
† From yearling ewe; not included in average.

The data on sex are obscured somewhat by the presence of singles and twins, and the data on singles and twins are obscured by the presence of males and females. The numbers are not sufficient to allow the segregation on the basis of both sex and plurality. Unpublished data by Winters from another experiment show male lambs at birth to be about 8 per cent heavier than females. The data in this experiment indicate that sex does not markedly influence weight.

WEIGHTS OF UTERI, MEMBRANES, AND UTERINE FLIUD COMPARED WITH WEIGHTS OF FETUS AT RESPECTIVE STAGES

With twins the uterus and membranes at the various stages were, roughly, one and one-third times the weight of the uterus and membranes when only a single fetus was carried. These weights plotted on coordinate paper (Fig. 10) show that when a single is carried the fetus comes to equal the weight of the uterus and membranes at about 100 days.

Table 4.—Size of Singles and Twins

Age of fetus	Weight			Forehead-rump length		
	Singles	Twins	Advantage of singles	Singles	Twins	Advantage of singles
days	gm.	gm.	gm.	cm.	cm.	cm.
34	2.20	.....	.....	3.12	.....	.....
36	3.77	3.46	+0.31	4.05	3.74	+0.31
38	.....	4.69	.....	.....	4.23	.....
42	7.36	7.30	+0.06	5.38	5.35	+0.03
46	12.29	16.00	−3.71	7.25	7.49	−0.24
52	28.85	32.48	−3.63	9.35	9.60	−0.25
58	64.00	64.37	−0.37	12.20	12.11	+0.09
66	119.42	138.35	−18.93	15.28	14.83	+0.45
74	.....	236.60	.....	.....	19.18	.....
84	448.41	430.91	+17.50	23.85	23.53	+0.32
94	.....	762.73	.....	.....	28.20	.....
104	1270.85	1218.25	+52.60	33.88	32.63	+1.25
116	2086.33	.....	.....	38.43	.....	.....
128	.....	2713.00	.....	.....	42.89	.....
140	3995.00	3292.67	+702.33	47.40	43.33	+4.07

Table 5.—Weights of Uteri and Membranes

Age of fetus	Unopened Uteri		Uterus and membranes		Uterine fluid	
	Average of singles	Average of twins	Average of singles	Average of twins	Average of singles	Average of twins
days	gm.	gm.	gm.	gm.	gm.	gm.
34	211.16	.....	121.40	.....	87.56	.....
36	199.00	408.23	84.70	176.00	.....	225.31
38	.....	395.69	.....	119.34*	.....	.....
42	318.95	544.31	186.35	304.02	125.24	225.69
46	657.71	918.52	397.85	505.79	247.57	380.53
52	771.10	1281.39	482.86	699.57	259.39	516.86
58	1133.98	1825.70	738.83	1122.63	331.15	574.33
66	1508.19	2381.35	907.18	1292.73	481.59	811.92
74	.....	2487.19	.....	1122.63	.....	880.00
84	2131.87	3674.08	963.88	1313.41	719.59	1496.85
94	.....	4490.54	.....	1572.45	.....	1392.63
104	3175.13	5465.76	1111.30	1451.49	792.99	1577.77
116	4059.63	.....	960.10	.....	1013.20	.....
128	.....	9971.42	.....	1738.76	.....	2806.66
140	7257.44	12005.02	1270.05	1905.08	1992.39	3514.60

* Uterus minus membranes.

When twins are carried a single fetus does not equal the weight of the uteri and membranes until about 108 days.

The amount of uterine fluid was found to be related to the number of fetuses, it being much greater for twins than for a single. When twins are carried this fluid is always slightly greater than the weight of a single fetus from the 105-day stage to the end of gestation. When a single is carried, the fluid equals the weight of the fetus at 94 days and diminishes relatively from then on. These data are presented graphically in Figures 10 and 11.

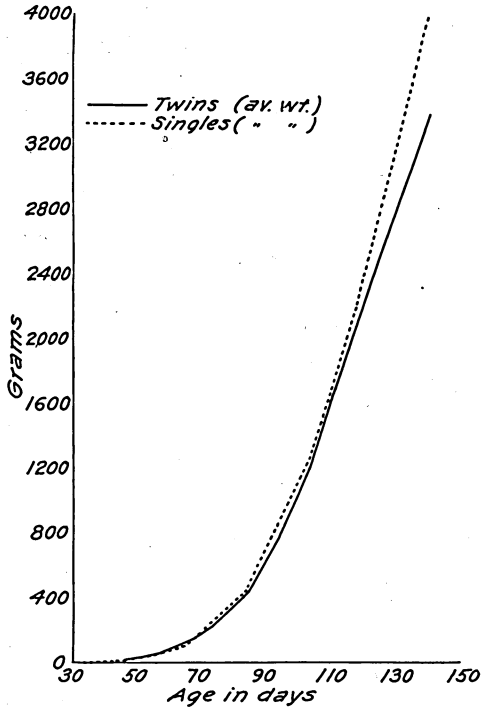

FIG. 9. WEIGHT OF SINGLES AND TWINS (SHEEP FETUS) BY AGE

The 46 ewes possessed 73 fetuses and 79 corpora lutea. Two resorptions were found in advanced stages of degeneration. In one of the cases of resorption, normal twin fetuses and only two corpora lutea were present. This appears to have been a case of identical twins. It is the first indication of identical twins in sheep from the Minnesota experiments. In the other case of resorption all that remained was the definite placental attachment with some remnants of the fetal membranes and a mass of yellowish brown material.

Nearly 8 per cent of the eggs ovulated did not develop, based on the data from the corpora lutea and fetuses. In swine Warwick (1928) found that 28 per cent of the ova were unaccounted for at the estimated age of 110 days. Ibsen (1928) found fetal resorption a common occurrence in guinea pigs. Davidson (1930) reported 7 to 14 per cent fetal degeneration in pigs as due to causes other than vitamin E deficiency.

Four corpora lutea by macroscopic examination appeared single but when examined microscopically, each was found to be two corpora lutea which had fused. The point of fusion of two corpora lutea is illustrated in Figure 12. This fact reveals the likelihood of error in attempting to establish identical twins on the basis of macroscopic examination of the corpora lutea.

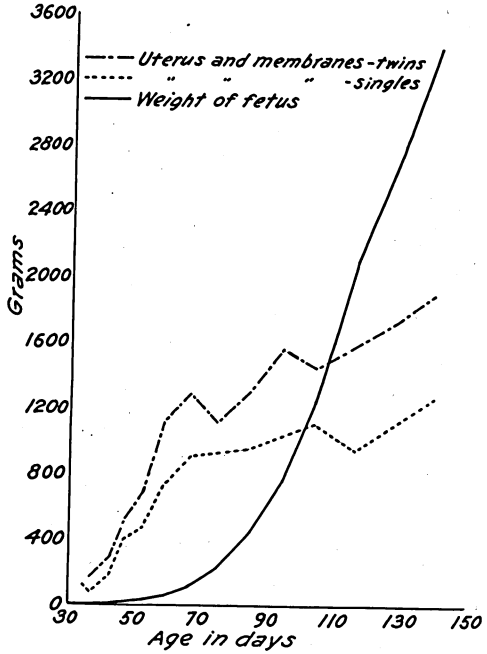

FIG. 10. WEIGHT OF UTERUS PLUS MEMBRANES WHERE SINGLES AND TWINS ARE CARRIED IN RELATIONSHIP TO AVERAGE WEIGHT OF A SINGLE FETUS

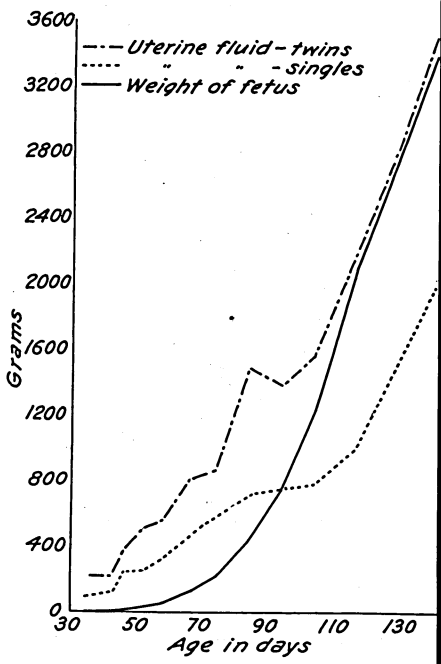

FIG. 11. WEIGHT OF UTERINE FLUID WITH SI AND TWIN FETUSES IN COMPARISON TO THE WEIGHT OF A SINGLE FETUS

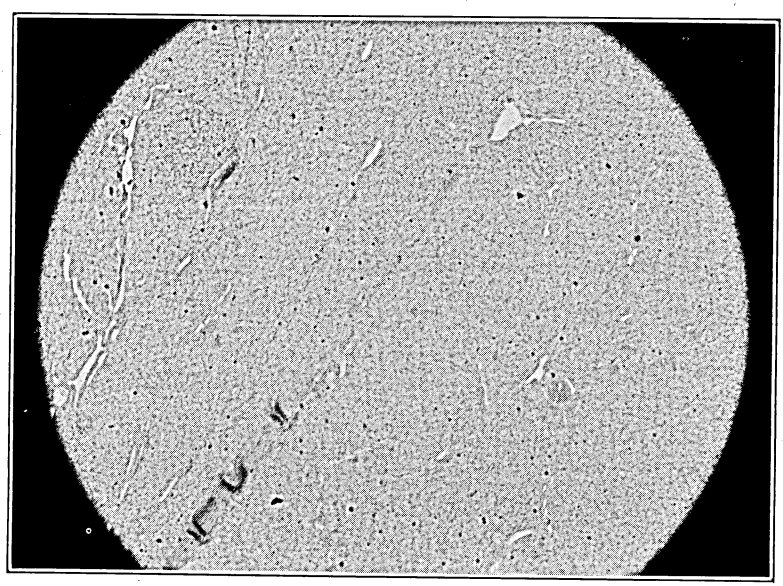

FIG. 12. FUSION OF TWO CORPORA LUTEA

SUMMARY

Forty-six mature grade Shropshire ewes were used in this experiment. Their oestrus cycles were determined by testing with rams, properly approned to prevent service. The ewes were bred near the cessation of their second experimental heat period.

The ewes were slaughtered so that 15 fetal developmental stages could be studied. Seventy-three fetuses were weighed and measured, and 15 representative photographs, one from each stage, were taken (Figs. 1 and 2).

The data collected show fetal development in the sheep to be most rapid during the early stages. There were several periods during which the rate of development appeared almost constant. However, no definite breaks between these periods are evident, and the authors believe that larger numbers and more frequent distribution would tend to smooth the curve rather than accentuate the breaks.

A comparison of the three groups studied showed no difference in the rate of fetal development or size of fetus despite the fact that two of the ewe groups differed considerably in size and two in the plane of nutrition.

The data show singles to be slightly larger than twins from 70 days on.

Inasmuch as no consistent differences were found between the groups at the respective stages, the authors feel justified in bulking the data obtained for each stage. It is believed this grouping shows "normal" fetal development in the sheep.

Table 1 is a summary of the averages of the measurements of the various body parts at the respective stages of fetal development. The data in this table represent the primary objective of this investigation. It is expected that these averages will be useful as a standard of normal development. With these data for comparison, it will be possible to judge the effects of various environmental factors on fetal development. It is also expected that these data will be useful as a reference guide in estimating the age of specimens obtained at random.

ACKNOWLEDGMENTS

The photographs were made by Mr. V. P. Hollis, Director of the Photographic Laboratory of the University of Minnesota, and the graphs were drawn by Mr. G. D. George.

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